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Tropical and high-latitude surface ocean circulation across the mid-Pleistocene transition: teleconnections and impacts for ice-sheet growth

E.L. McClymont (1), A. Rosell-Melé (2)

(1) School of Geography, Politics & Sociology, Newcastle University, Newcastle upon Tyne, NE1 7RU, United Kingdom, (2) ICREA and Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Cerdanyola del Valles, 08193 Spain (erin.mcclymont@ncl.ac.uk / antoni.rosell@uab.cat)

The Mid-Pleistocene Transition (MPT) is a major event in the Quaternary record, marking the shift to a dominant glacial/interglacial period of 100-kyr and the development of larger northern hemisphere ice-sheets at ca. 0.9 Ma. The significance of the MPT lies in the change of the global climate system response to external insolation forcing, which cannot account for the strength of the 100-kyr cycles. Several existing hypotheses link the MPT to changes in the size and dynamics of the northern hemisphere ice-sheets. Under these scenarios, the ice-sheets introduce non-linearity into the climate system and drive the shift towards 100-kyr cycles due to their increased inertia and through feedbacks including more vigorous atmospheric circulation, perturbations to thermohaline circulation, and changing carbon cycle dynamics. Alternatively, the changes to the northern hemisphere ice-sheets associated with the MPT could reflect the result of feedbacks elsewhere in the climate system, including changing sea-ice distribution, cooler deep-water temperatures, and/or more vigorous atmospheric circulation.

Here, we present alkenone-derived records of sea-surface temperature from the north Atlantic and north Pacific Oceans, coupled with evidence of arctic/polar water mass distributions, spanning 1.5-0.5 Ma. We compare these to sea-surface temperature records from the tropical Pacific and the south-east Atlantic. At all sites we find evidence for cooling beginning from 1.15 Ma, supporting the hypotheses invoking cooling of both the atmosphere and deep-waters as a driver of the MPT. Sea-ice expansion

from 1.15 Ma is suggested by the equatorward migration of arctic/polar water masses in both the Atlantic and Pacific, which reached their maximum extent at 1.0 Ma. The negative impact of more expansive sea-ice cover to the transport of moisture to the ice-sheet source regions may have been critical to the later development of larger northern hemisphere ice-sheets from 0.9 Ma. Significantly, we also find that the MPT was not simply a high-latitude phenomenon, but was accompanied by significant changes to circulation in the tropical Pacific and south-east Atlantic between 1.15 – 0.9 Ma. Modern teleconnections associated with the El Niño/Southern Oscillation suggest that these changes would have increased moisture transport to the ice-sheet source regions of boreal North America and encouraged the northern hemisphere ice-sheet expansion at 0.9 Ma. Although tropical Pacific circulation changed favourably with respect to ice-sheet growth from 1.15 Ma, the changes to water mass distributions in the N Atlantic and N Pacific potentially modulated the ice-sheet response to these changes delaying any potential growth in the northern hemisphere ice-sheets until 0.9Ma.